A 30-MC 120-DB I-F AMPLIFIER WITH 600-KC 3-DB BANDWIDTH

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I. INTRODUCTION

The primary problem in designing a high-frequency transistor amplifier with very narrow bandwidth is the potential instability of transistors at high frequencies. The problem is aggravated when high-Q tuned circuits are used as the loads because of the rapid phase change of such loads with frequency. Other factors, such as the noise figure, the sensitivity of gain and alignment to changes in transistor parameters, power-supply voltage, and temperature, must also be taken into consideration, particularly when such amplifiers are designed for instrumentation use.

A 30-Mc 120-db i-f amplifier with a 600-Kc 3-db bandwidth for use with a transfer function and impedance bridge was built without neutralization using Fairchild silicon planar transistors type 2N918 having an f_t of 900 Mc and a C_{ob} of 1.7 pf max at $V_{CB} = 10$ V. By treating several amplifier stages as a unit, it was possible to minimize the stability margin safely and to control the sensitivity of the amplifier to variations in the parameters concerned.

II. GENERAL DESCRIPTION

The amplifier circuit shown in Fig. 1 consists of five synchronous single-tuned stages, the first of which is matched to a source resistance of 50 ohms. The tuned circuit of each stage has a higher Q than that of the preceding stage. The first four stages are common-emitter, transformer-coupled, using 2N918 transistors. The fourth and fifth stages are cascode-connected, Q_5 being a Fairchild 2N3137. D_1 and D_2 are Fairchild FD600 silicon epitaxial diodes.

Erie N500, 8-25 pf capacitors were used as trimmers for the tank circuits. In each tank circuit the coil was fastened to the capacitor in order to fix the value of stray capacitance between coil and trimmer. A typical tank circuit unit is shown in Fig. 2. Coil specifications are given in Table I.

III. PERFORMANCE

Performance data are given in Table II and the results of tests of gain and midfrequency stability in Table III.

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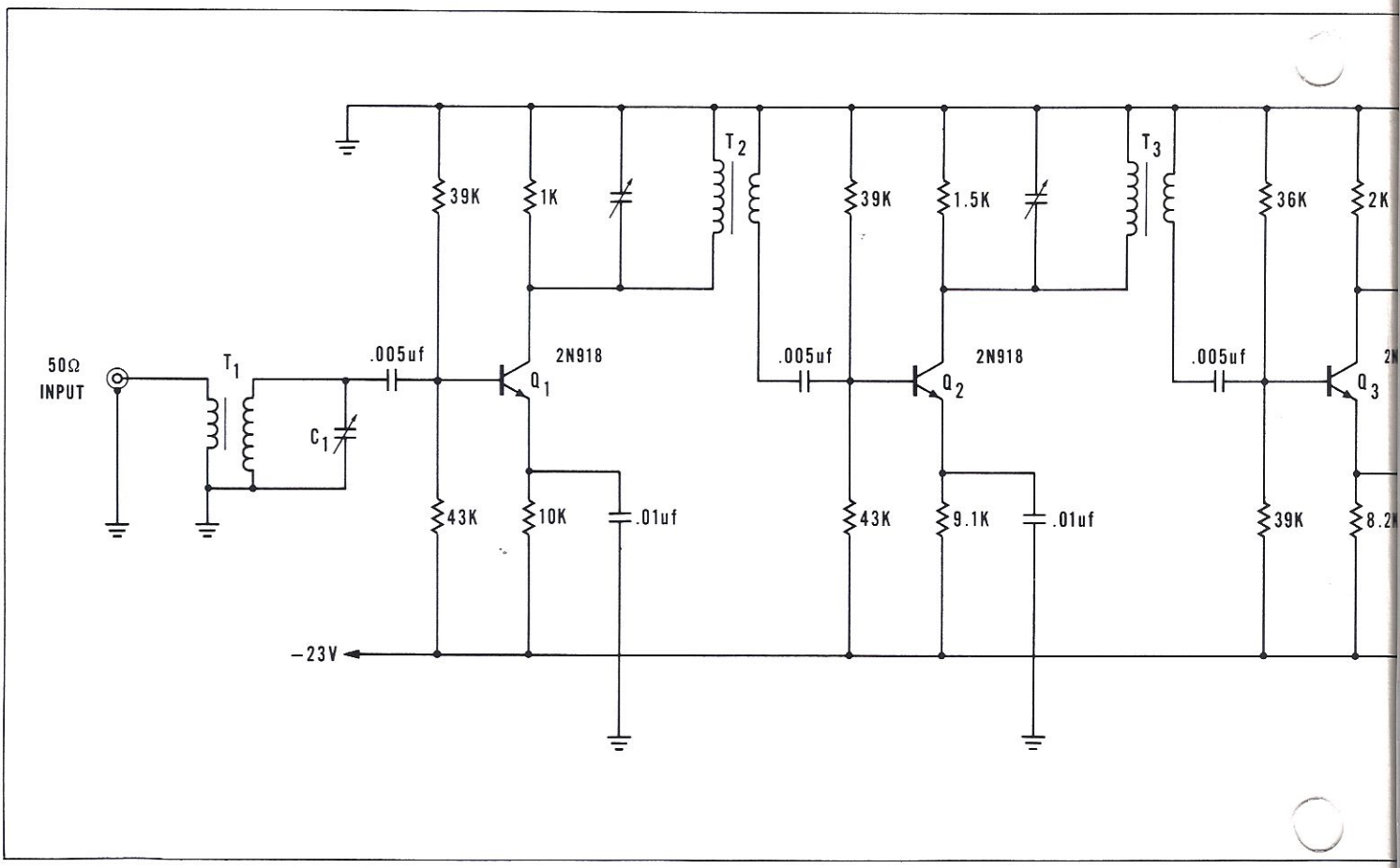
FIG. 1. SCHEMATIC OF 30-MC



IV. DESIGN

Design considerations

An amplifier of five identical synchronous single-tuned stages with a bandwidth of 600 Kc requires a midfrequency stability, $|\Delta f_o|/f_o$, of less than 2.58% and a corresponding stability of tank circuit components, $|\Delta C/C + \Delta L/L|$, of less than 5.1% in order to hold the midfrequency within the 3 db points despite changes in temperature and transistor parameters. Not only would a smaller stability margin than this be difficult to achieve with standard components and devices, but a bandwidth of substantially less than 600 Kc with a 5-stage amplifier would require higher Q tank circuits which are likely to provoke oscillation.

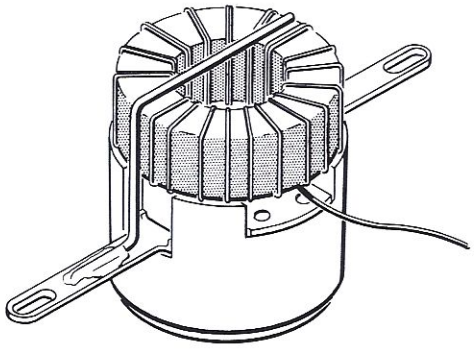
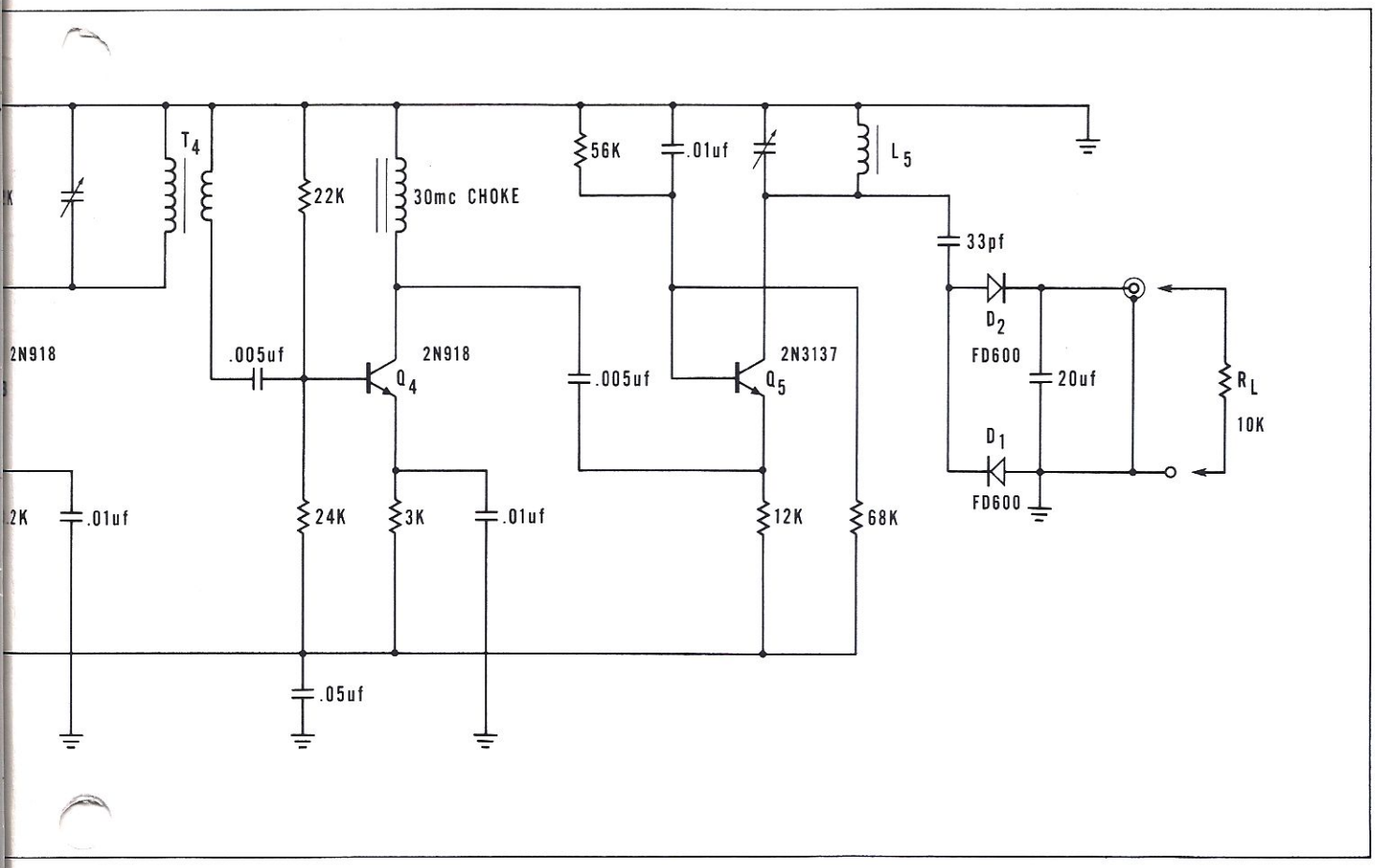


Fig. 2. Tank circuit detail.

Design procedure

The conventional method of designing cascaded amplifiers stage by stage using the stability factor S for each stage leads to a stability margin larger than necessary and does not permit consideration of the sensitivity of gain to changes in temperature, supply voltage, and transistor parameters. A new approach to the design of multistage amplifiers was therefore investigated and applied to the amplifier

C NARROW-BAND AMPLIFIER



described here in the following way:

The amplifier was considered as consisting of two sections:

1. Q_4 and Q_5 in cascode, providing 40 db gain with a load of 10 KΩ.

2. Q_1, Q_2, and Q_3, providing 80 db gain with the input matched to 50 Ω.

The latter was treated as a unique network. The gain and the total input admittance, $Y_t(s)$, which is the sum of the source admittance and the input admittance of the amplifier (Q_1, Q_2, Q_3) loaded by the cascode (Q_4, Q_5) were expressed using as parameters the values of the tank circuit components, the transformer turns ratios, and the transistor parameters. Tank circuit conductances and transformer turns ratios were then chosen to meet the following conditions:

1. $Y_t(s)$ must be a Hurwitz polynomial. *

2. The loaded Q_L of the tuned circuits must exceed a minimum imposed by the bandwidth.

3. The amplifier must have the required volt age gain.

4. Sensitivity of gain to changes in tempera ture, supply voltage, and transistor parameters must be minimum.

5. The unloaded Q_0 of each tuned circuit must be substantially higher than the loaded Q_L, i. e.,

$$\frac{Q_0}{Q_L} > 10$$

Thus the total conductance g_L will be much less dependent on frequency.

ACKNOWLEDGEMENT:

Measurements for the data presented in this paper were made by N. Dale Swartz.

*Information on Hurwitz polynomials may be found in "Transistors and Active Circuits," by J. C. Linvill and J. F. Gibbons, McGraw Hill Book Co., and in other sources.

TABLE I

COIL SPECIFICATIONS*

Unit	N_p	N_s
T_1	5	15.5
T_2, T_3, T_4	17.5	4
L_5	16.5	- -

*Arnold powdered iron toroids AU-310-125 SF were used in all units.

TABLE II

PERFORMANCE DATA

Conditions: f_o = 30 Mc; R_s = 50Ω; R_L = 20KΩ; V_{CC} = 22V

Voltage gain	120 ±1	db
Noise figure	< 4.5	db
3-db bandwidth	650 ±50	Kc
6-db bandwidth	≈ 1.2	Mc
10-db bandwidth	≈ 2	Mc
15-db bandwidth	≈ 3	Mc

TABLE III

TEST DATA

Test Conditions	ΔG (db)	Δf_o (Kc)	Δ B.W. (%)
Temperature increased from 25°C to 65°C	-3	imperceptible	imperceptible
V_{CC} increased from 20 V to 24 V	+7	100	—
Substitution of 3 randomly chosen sets of transistors, package type unchanged (case grounded)	< 3	< 200	10
Substitution of one randomly chosen set of transistors, different package (case not grounded)	< 4	< 300	30